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Three-dimensional analysis of facial morphology: growth, development and aging of the orolabial region.

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Summary

Soft tissue analysis plays an increasing, strategic role in the recognition of facial alterations, but there are scanty three-dimensional reference data during normal growth, development and aging. In the current study, 532 male and 386 female healthy subjects aged 4 to 73 years were analyzed using a non-invasive, computerized electromagnetic digitizer, and normal dimensions of mouth and lips were obtained in the three-dimensional space. Labial thickness and curvature were also assessed in a selected group of 40 men and women, equally divided into young (age 21-30 yr, mean 25 yr) and old persons (age 45-65 yr, mean 55 yr).
Lip vermilion area to volume, and vermilion height to cutaneous lip height ratios decreased with age in both sexes. On average, the lips were thicker in men and in young persons than in women and in old persons. Mean labial curvature was larger in young men than in the other groups, and it was more variable in young than in old persons. Data collected in the present investigation can be used as a data base for the quantitative description of human lip morphology during normal growth, development and aging.

Key words

Digital anthropometry; lips; growth; aging.

Introduction

Soft tissue analysis plays an increasing strategic role in the recognition of facial alterations. In particular, the mouth and lips play a key role in the face from all points of view (anatomical, functional, esthetical), and the quantitative assessment of their three-dimensional characteristics can provide useful information for diagnosis, treatment planning and evaluation of medical and surgical treatments. Currently, there are scanty three-dimensional reference data during normal growth, development and aging. In both sexes, after childhood and adolescent growth and development, all parts of the face continue to modify during adulthood, even after the attainment of biological maturity (Akgül and Toygar, 2002; Ferrario et al., 2000; Iblher et al., 2008; Lévêque and Goubanova, 2004; Sawyer et al., 2009; Sforza et al., 2009).

A complete assessment of these structures should consider both the external and the internal surfaces, but in the living subject this objective can be obtained only with computed tomography or magnetic resonance imaging (Iblher et al., 2008). Unfortunately, these two methods cannot be used for widespread data collection in normal persons, for both health (radioprotection) and economics reasons. In our laboratory,

we have developed three-dimensional non-invasive methods that can be used for a quantitative assessment of labial morphology in normal people.

In the current study, we report a first set of data on labial dimensions in a group of healthy men and women aged 4 to 73 years.

Materials and Methods

Two groups of healthy white Italians were analyzed. Participants and parents of the subjects underage were informed about all the adopted procedures, and gave their consent to the investigation. All procedures were not invasive.

In the first group, 918 people (532 men, 386 women) aged 4 to 73 yr were studied (Sforza et al., 2009). Their external labial dimensions were assessed using a contact digitizer. In brief, in all subjects the three-dimensional (x, y, z) coordinates of selected facial landmarks were collected using a computerized electromagnetic digitizer. In particular, the following labial soft tissue landmarks were considered (Ferrario et al., 2000). Midline landmarks: sn, subnasale; ls, labiale superius; sto, stomion; li, labiale inferius; sl, sublabiale. Lateral landmarks (on both sides): cph, crista philtri; ch, cheilion. The coordinates of the landmarks were used to calculate lip vermilion area, lip volume, total vermilion height (ls-li) and total (cutaneous) lip height (sn-sl). The area to volume, and the vermilion height to lip height percentage ratios were computed.

In the second group of subjects, labial impressions of the external (cutaneous) and internal (mucosal) labial surfaces were obtained in 20 men and 20 women, and cast in dental plaster (Ferrario et al., 2009). Subjects were divided into a "young" (21-30 yr) and an "old" (45-65 yr) group. Labial casts were digitized, mathematically reconstructed by a three-dimensional mesh, and morphometric evaluations performed. In particular, three-dimensional lip thickness (mm) and labial curvature (mm^{-1}) were obtained. The three-dimensional mean curvature of the external labial surface was computed by calculating for each vertex of the mesh the osculating circles of the two principal axes of curvature, and obtaining the average of the two. The osculating circle is the tangent circle at a given point that approximates the curve most tightly. The procedure was performed for all parts of the mathematically reconstructed surface.

For each subject, the mean value of the inverse of the radii of all the mean osculating circles (mean curvature between the two principal axes), and the relevant SD, i.e. standard deviation, were computed. The inverse of the mean radius represents the local curvature: a plane surface has two principal axes whose osculating circles have an infinite radius (and their inverse is a null curvature); the more a surface is curved, the lesser the radii of its osculating circles, and the larger its inverse. The SD is an index of the intrinsic variations in labial curvature.

Results

All measurements modified as a function of age. Lip vermilion area to volume ratio decreased with age in both sexes, ranging from 12-13% in the youngest children to 4-5% in the oldest adults (Fig. 1). The decrement was similar in the two sexes until

40-45 years of age, subsequently women maintained a somewhat larger area to volume ratio than men.

A similar age-related trend was observed for the vermilion height to cutaneous lip height ratio: at 4 years of age, the vermilion and cutaneous lip heights were similar (the vermilion/ total height ratio was approximately 43%), but in the eighth decade of life the ratio was only 28%. The decrement was particularly evident in men, and it began in young adulthood.

On average, the lips were thicker in men and in young persons than in women and older persons (young men: 14.6 mm; old men: 10.7 mm; young women: 12.3 mm; old women: 9.1 mm). Mean labial curvature was larger in young men than in the other groups; overall, lip curvature in young persons appeared to be more variable than in older persons, the effect was more evident in men (young: mean 0.0130 mm^{-1}, SD 0.1414; old: mean 0.0061 mm^{-1}, SD 0.0839) than in women (young: mean 0.0059 mm^{-1}, SD 0.0999; old: mean 0.0072 mm^{-1}, SD 0.0795).

Discussion

In the current study, lip dimensions were found to change between childhood, adolescence and young adulthood, and even later on into the eighth decade of life. Aging involved reduction in labial thickness and in vermilion dimensions, coupled with increase in the distance between the nose and the upper lip vermilion border (Akgül and Toygar, 2002; Iblher et al., 2008; Lévêque and Goubanova, 2004; Sawyer et al., 2009).

Overall, the age-related reduction in the two analyzed ratios (vermilion area to volume, and vermilion height to total height) were in good agreement with previous cross-sectional reports, both in children (Ferrario et al., 2000; Mori et al., 2005; Zhu et al., 2008) and in adults (Iblher et al., 2008; Sawyer et al., 2009). Additionally, the decrements in vermilion area, height and thickness matched well with longitudinal records (Akgul and Toygar, 2002).

In a first approximation, the current values of labial curvature were computed considering all labial surfaces (upper and lower lip, vermilion and cutaneous part) as a whole. Indeed, further analyses should separate the various anatomical structures, and assess labial curvature in correspondence of selected landmarks. The current age-related variations in labial curvature cannot be compared to previous quantitative reports, and further analyses in larger samples are necessary; overall, the reduction in the standard deviation of labial curvature well describes the anatomical and clinical observations: aged lips are usually flatter and more even than young lips. As an example, Figure 2 reports the labial curvature of a young (A) and an old (B) woman. In the young lip, the philtrum is more delineated, while in the old lip all surfaces have smaller curvatures.

Gross anatomical (gravity; changes in posture; obesity) and histological factors (thinning of the skin and muscle; increase in subcutaneous fat; reduction in elastic fibres) may explain the modifications in facial dimensions with aging (Penna et al., 2009; See et al., 2008). Overall, aging does not involve a decrease but rather a redistribution of labial volume, with a reduction in the vermilion and a relative increment in the cutaneous part (Iblher et al., 2008).

Previous investigations that quantitatively analyzed the age and sex characteristics of the orolabial region used several two- and three-dimensional methods, but only Iblher et al. (2008) made three-dimensional assessments of lip thickness using magnetic resonance imaging. Unfortunately, their method cannot be proposed for widespread anatomical, anthropometric and clinical measurements. Additionally, their records were obtained with supine subjects, and the effect of gravity on the facial soft tissues has already been found to be particularly important for mid aged persons (See et al., 2008). In contrast, the method used in the present investigation can maintain the normal relationships between the various facial and head structures and can provide results more close to normal daytime conditions.

In conclusion, information about the normal sex- and age-related dimensions of the lips and mouth in healthy Caucasians was provided. The analyzed age interval covered eight decades of life, being probably the widest reported in literature. Data could be used for the quantitative description of mouth and lip morphology during normal growth, development and aging.

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Figures

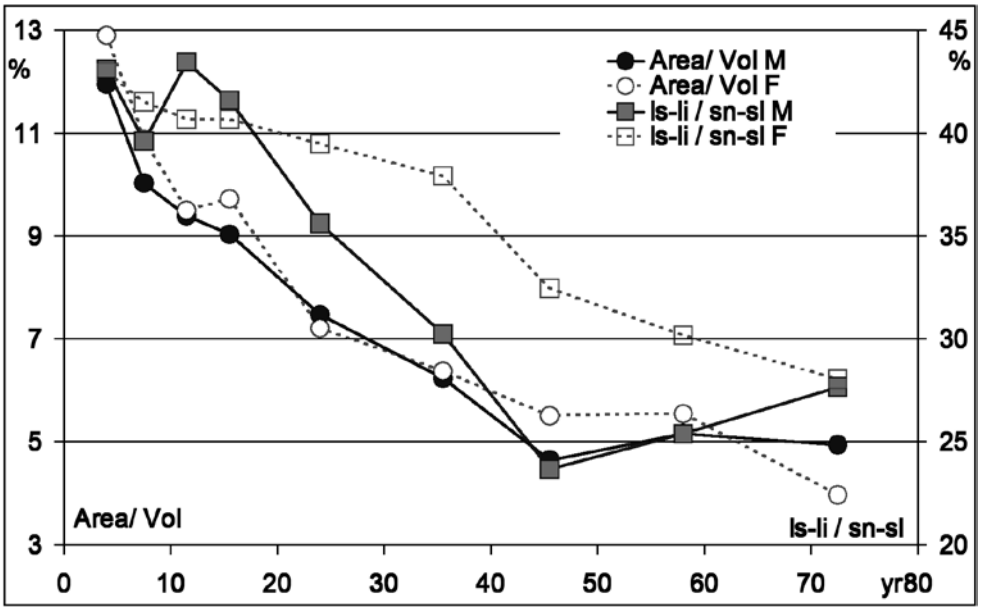

Figure 1 – Percentage ratios between lip vermilion area and volume (men: black dots, continuous line; women: open dots, interrupted line) and between vermilion height and cutaneous lip height (men: black squares, continuous line; women: open squares, interrupted line), as a function of age.

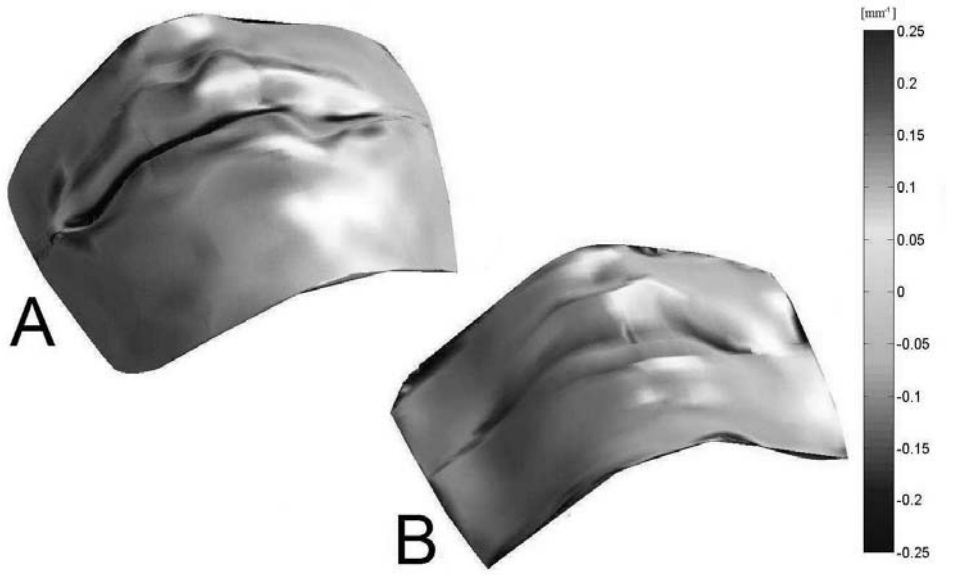

Figure 2 – Three-dimensional labial curvature of a young (A) and an old (B) woman.